

FUTURE SPIN EXPERIMENTS AT SLAC

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**Representing
THE REAL PHOTON COLLABORATION**

Sept. 2002

- **COHERENT PHOTON BEAM**
 - POLARIZED
 - QUASI-MONOCHROMATIC
 - HIGH INTENSITY
- **E161: GLUON POLARIZATION IN NUCLEON**
- **E159: GDH SUM RULE**
- **LONGITUDINAL POLARIZATION EFFECTS
ON OPEN CHARM**

REAL PHOTON Collaboration

Aarhus	Miss. State
BNL	Old Dominion
Florida Intl	SLAC
Frascati	UCLA,
JLab	UCT
Liverpool,	UMass
Los Almos	UVa
Saclay	UWits
Smith	William and Mary
Mainz	Yerevan

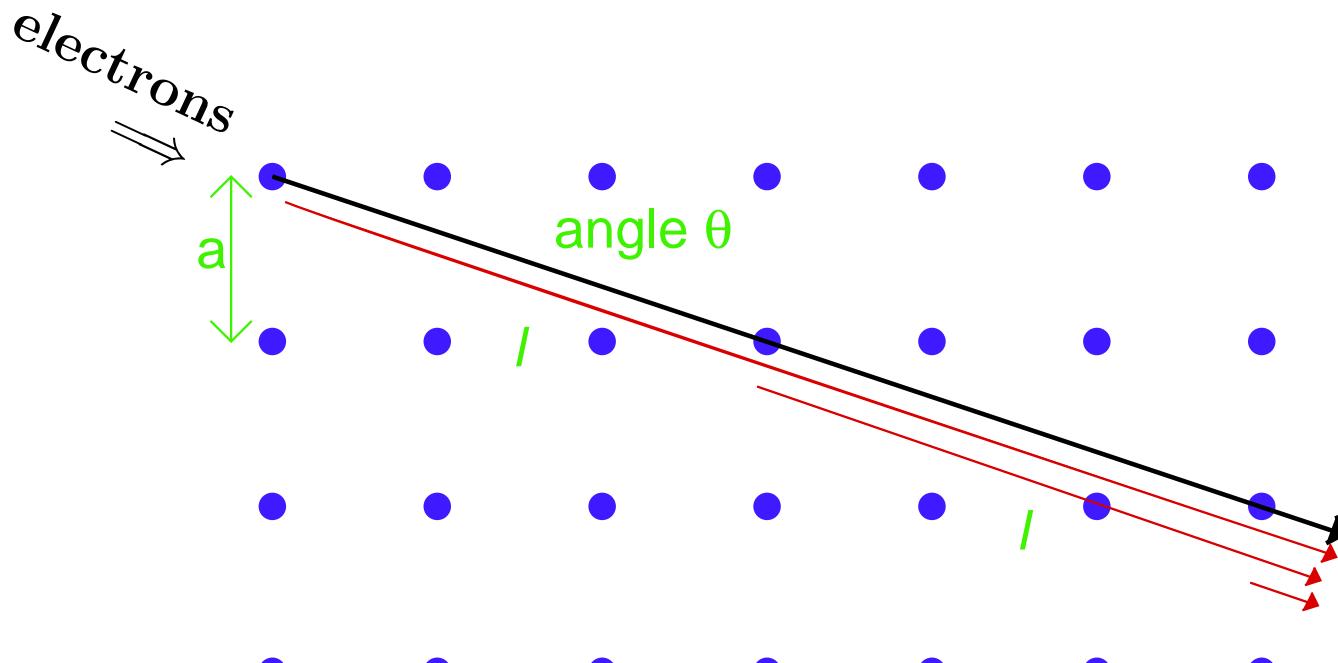
PRESENT AND FUTURE SPIN EXPERIMENTS AT SLAC

- PRESENT
 - POLARIZED MOLLER SCATTERING-E158
 - RUNNING NOW AND NEXT YEAR
 - ELECTRON-ELECTRON SCATTERING
 - MEASURE $\sin^2\theta_W$ at SMALL Q²
- APPROVED PHOTO-PRODUCTION EXPERIMENTS
 - E160: J/ ψ PROPAGATION IN NUCLEAR MATTER
 - E161: GLUON POLARIZATION IN NUCLEON
 - E159: GDH SUM RULE

COHERENT PHOTON BEAM

- SLAC POLARIZED (83%) HIGH INTENSITY ($3 \cdot 10^{12}$ /sec) ELECTRON BEAM PASSES THRU THIN CRYSTAL
- CONSTRUCTIVE INTERFERENCE OF PHOTONS AT CERTAIN ORIENTATIONS OF CRYSTAL
- DIAMOND THE BEST
- ENHANCEMENT OF BREMSTULUNG SPECTRUM AT SELECTED PHOTON ENERGY
- MORE FORWARD THAN ORDINARY BREM.
- PHOTONS KEEP MOST OF ELECTRON CIRCULAR POLARIZATION (AT HIGH PHOTON ENERGY)
- LINEAR POLARIZATION AT LOWER PHOTON ENERGIES

ELECTRONS GOING THRU CRYSTAL



- photon waves, velocity=1.
Want to be in phase.
- electron, velocity= β .
Lag by one photon wavelength over
distance a/θ

OVERVIEW OF COHERENT BREMSSTRAHLUNG

- Momentum transfer q very small. Minimum momentum transfer given by:

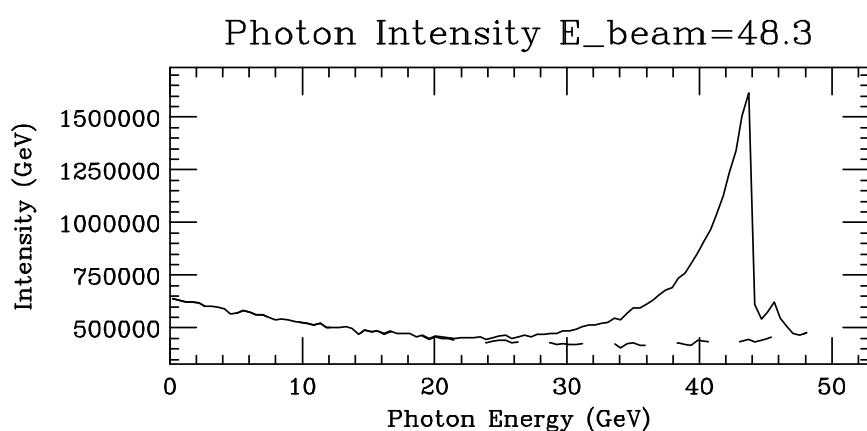
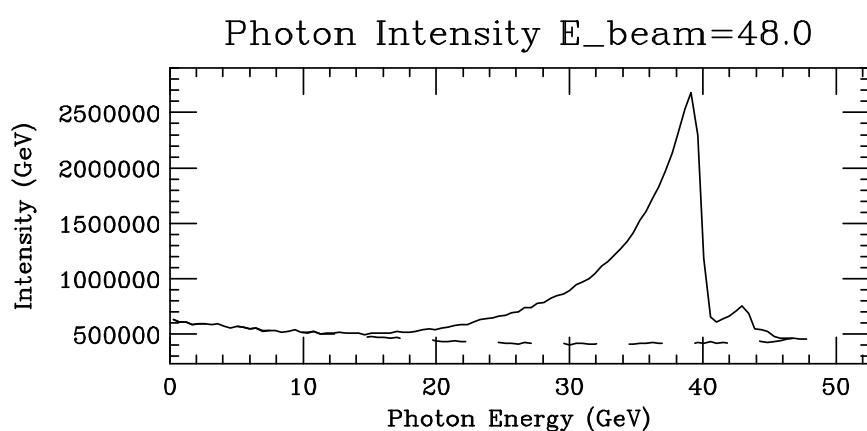
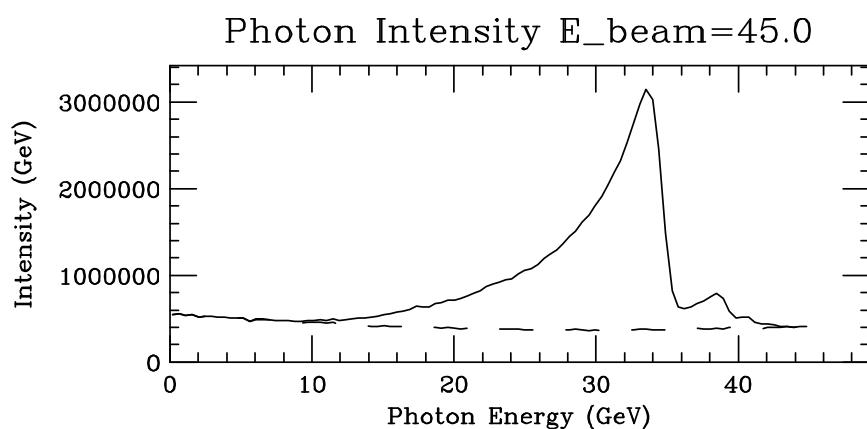
$$\delta = y/2E(1 - y)$$

where $y = k/E$, k is photon energy, E is electron energy (in electron mass units).

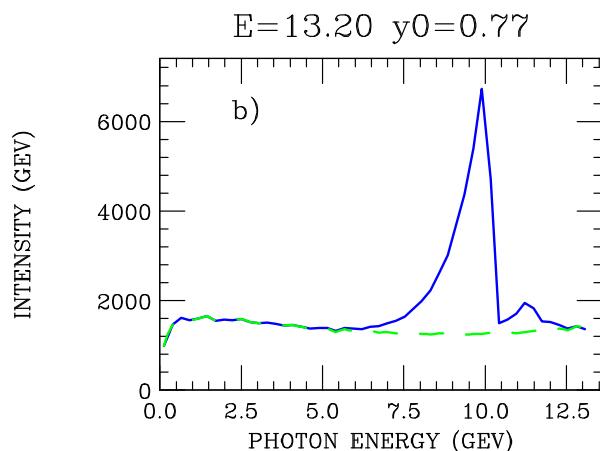
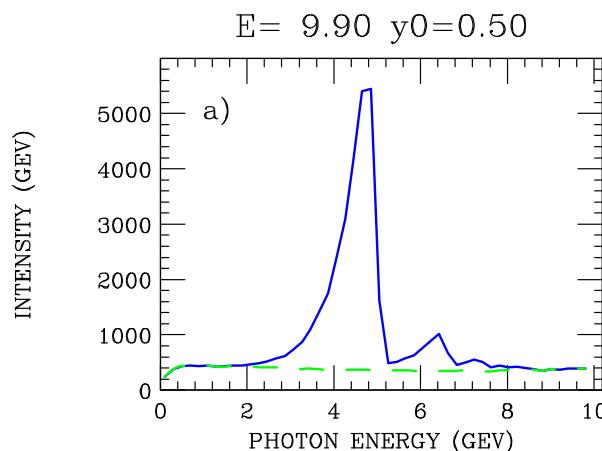
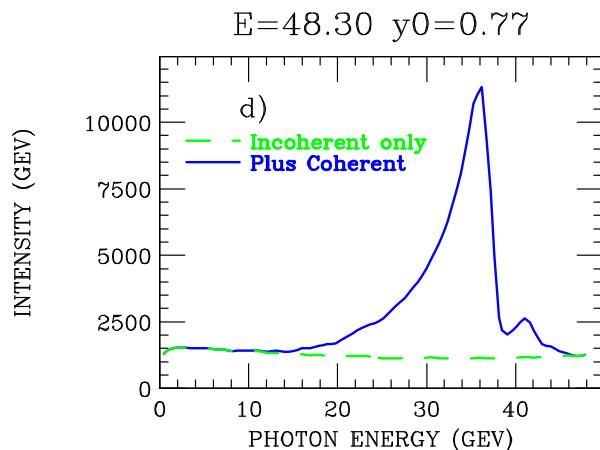
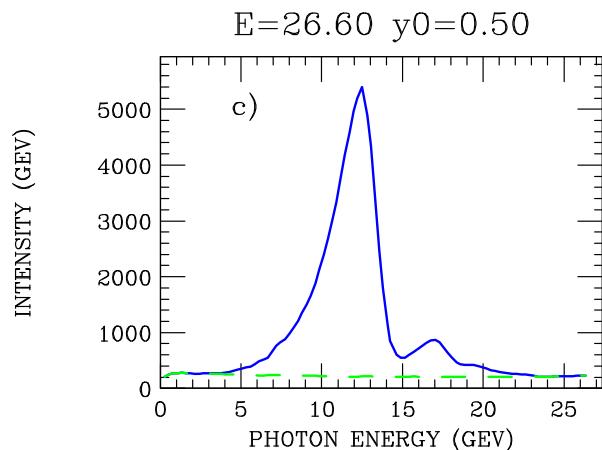
- Classical argument based on electron traveling slightly slower than photon. $\Delta l = l(1 - \beta)/\beta$, where $l = a/\theta$ is distance between two lattice rows with spacing a and an electron angle θ .
- For coherence, want $\Delta l = n\lambda$, where $\lambda = 2\pi/k$ is wavelength of photon. Combining, we find

$$n(2\pi/a) = \delta/\theta$$
$$\theta = \frac{y}{2E(1 - y)} \frac{a}{n2\pi}$$

INTENSITY SPECTRA FOR E161

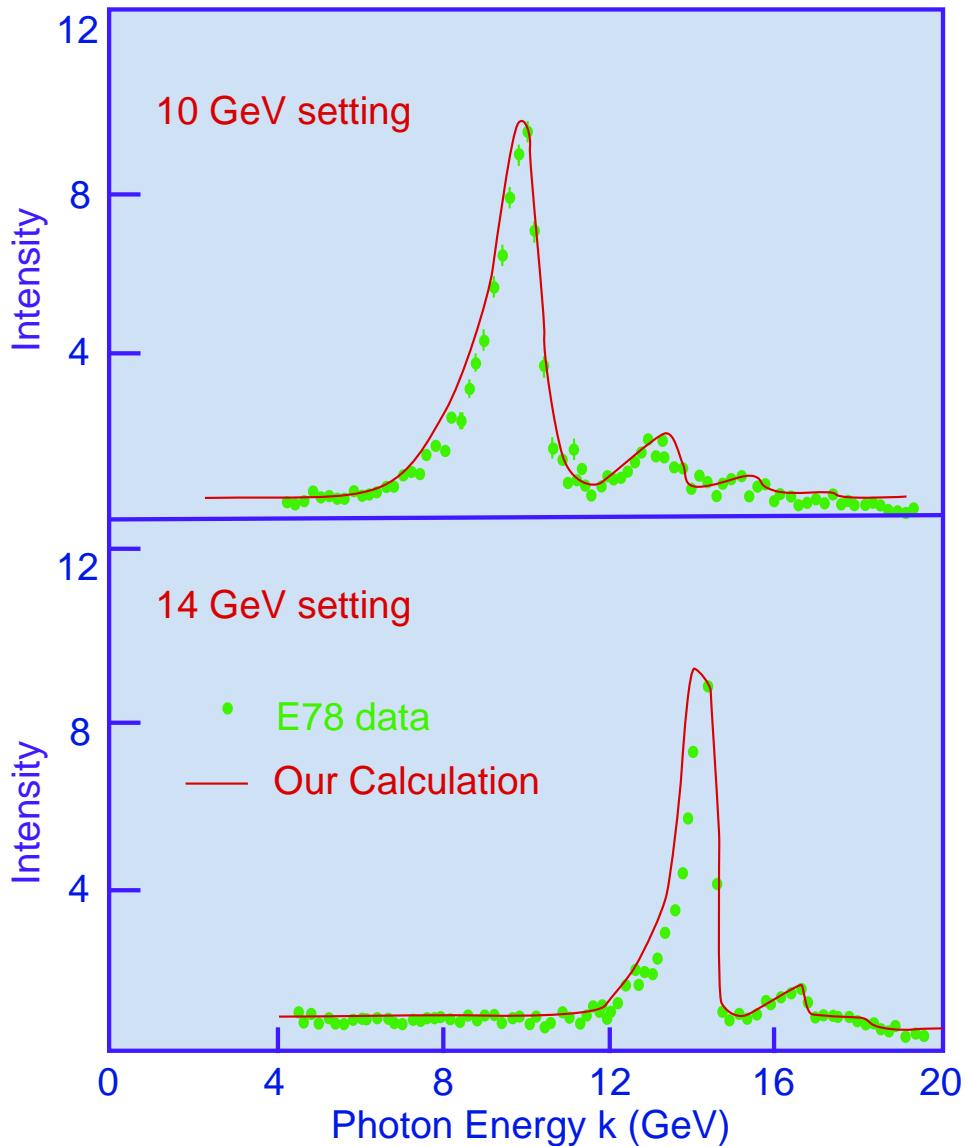


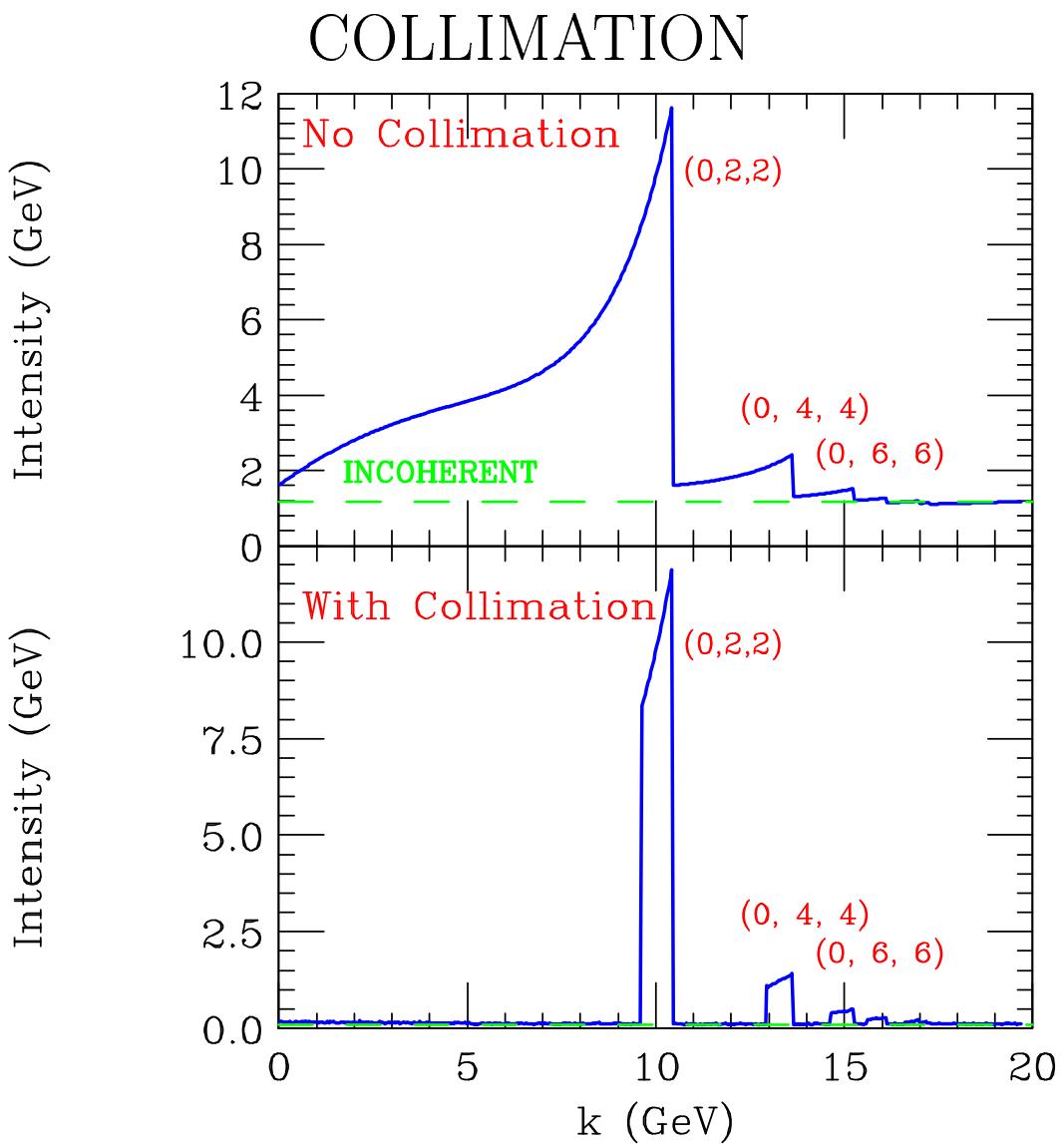
REPRESENTATIVE SPECTRA FOR E159



COMPARISON OF OUR CALCULATIONS WITH E78 MEASURED SPECTRA

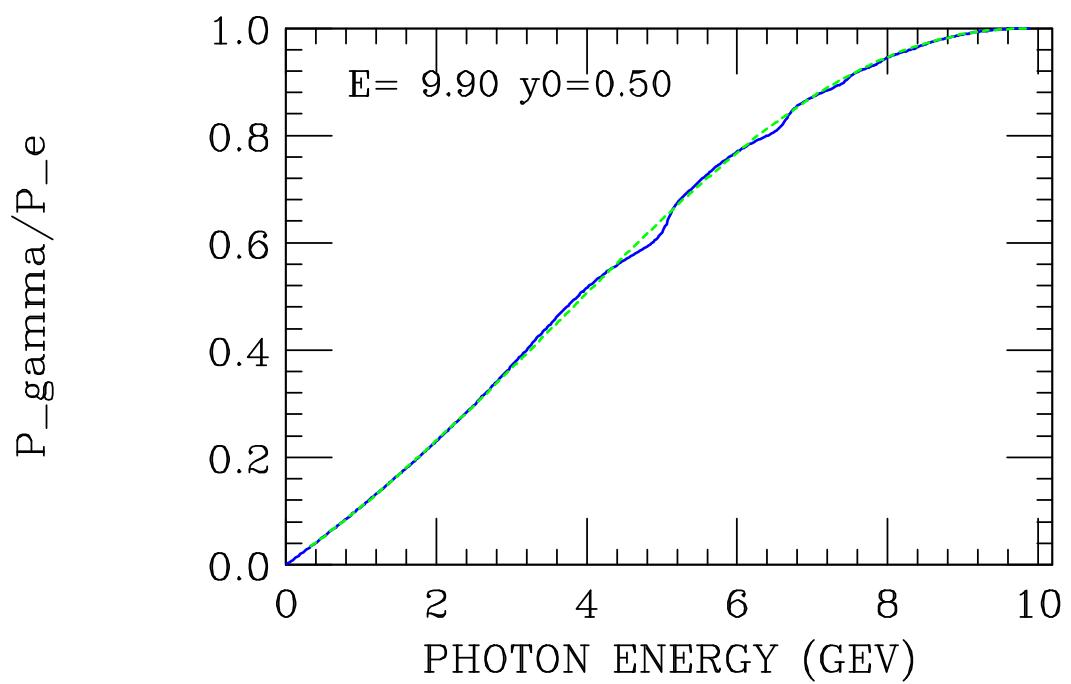
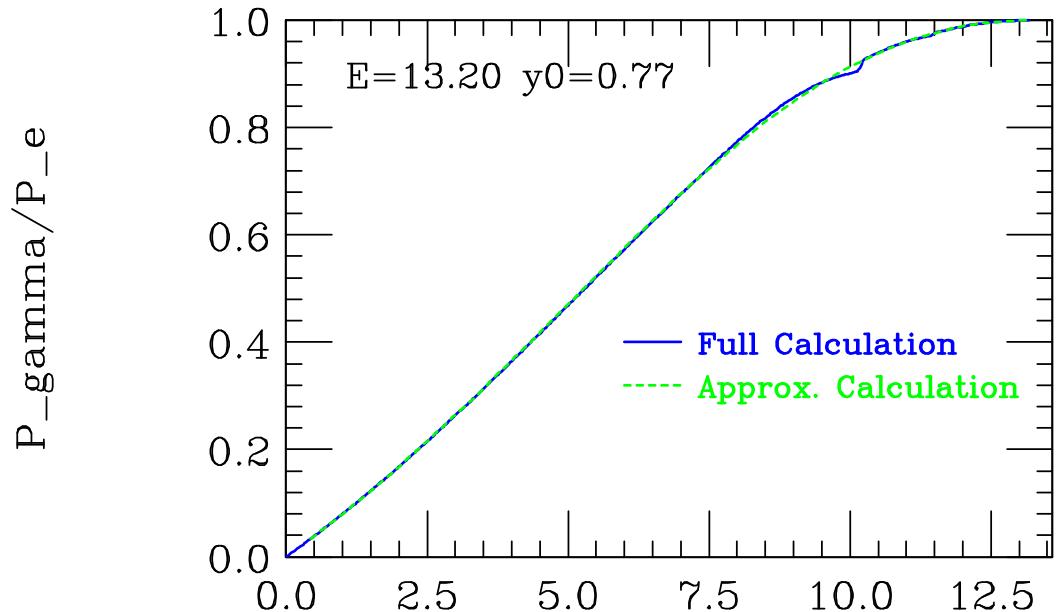
Actual spectra slightly narrower: mosaic spread and/or beam emittance? Electron beam energy was 19.7 GeV.





Effect of collimation in **ideal case** (no multiple scattering, mosaic spread, beam emittance).

PHOTON CIRCULAR POLARIZATION



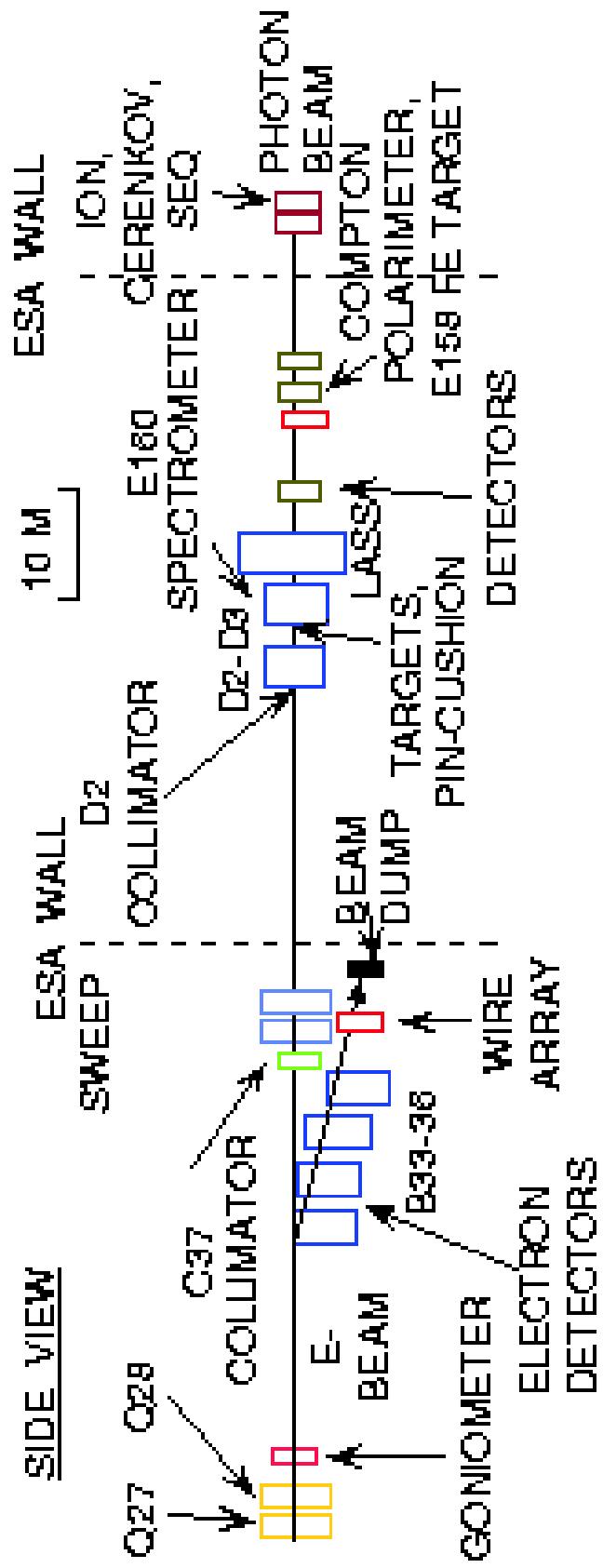
BEAM PARAMETERS FOR E161

- Diamond Radiation Length = 0.07%
- Maximum Radiation Length = 1.5%

Electron Energy (GeV)	45.1	48.3	48.3
Electron Current (10^{10} /spill)	2.0	2.0	2.0
Peak Photon Energy (GeV)	35.0	40.0	44.0
Photons (10^7 /spill)	2	1.5	1.1
Circular Polarization	0.75	0.80	0.84

Possible to have 1.5% RL Diamond and $5 \cdot 10^{10}$ electrons/spill Electron Current \Rightarrow $8 \cdot 10^8$ /photons/spill.

COHERENT BREMSSTRAHLUNG PHOTON BEAM LINE FOR E160



COMPTON POLARIMETER

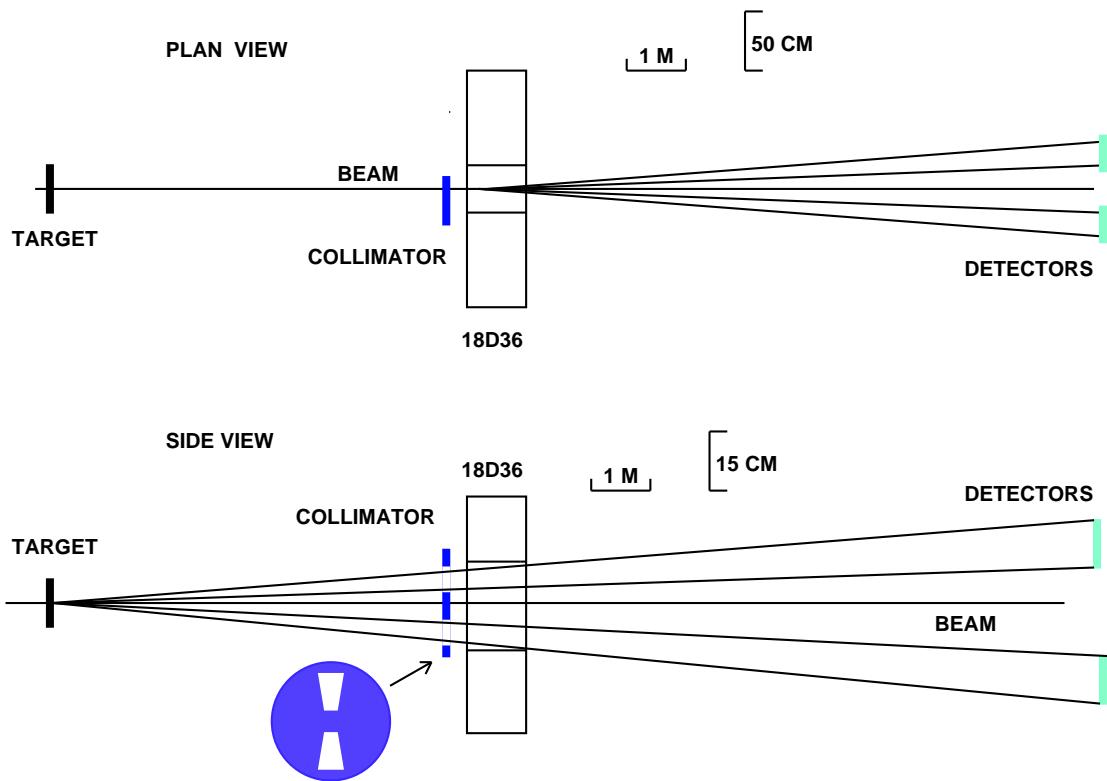
- Designed to measure flux, energy distribution, and circular polarization of beam photons.
- Use Atomic Compton scattering $\gamma e \rightarrow \gamma e$.

- Helicity-dependent cross section:

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{2m_e^2} \left(\frac{k}{k_0} \right)^2 \left[\frac{k}{k_0} + \frac{k_0}{k} - \sin^2 \theta - P_\gamma P_e (1 - \cos \theta) \cos \theta \frac{(k + k_0)}{m_e} \right],$$

- For flux measurements, electrons in NH_3 and ND_3 targets can be used for continuous monitoring.
- For circular polarization measurements, use special purpose iron target (similar to that used in E155, etc. for Møller measurements).
- Electrons in foil polarized using same magnet as for NH_3 (5 T). Expect average P_e about 0.08.

LAYOUT



3 PHOTO-PRODUCTION EXPERIMENTS

POLARIZED QUASI-MONO-ENERGETIC PHOTON BEAM

- E159: A DEPENDENCE OF CROSS SECTION FOR J/ψ and ψ'
 - J/ψ PROPAGATION IN ORDINARY MATTER (FOR QUARK-GLUON PLASMA)
 - COLOR TRANSPARENCY
- E161: GLUON POLARIZATION FROM OPEN CHARM
 - POORLY KNOW NOW
 - DIRECT MEASUREMENT
 - POLARIZED LiD TARGET 70%
 - MUON SPECTROMETER
- E159: GDH SUM RULE
 - FUNDAMENTAL SUM RULE
 - Total Hadronic Cross Section Asymmetry

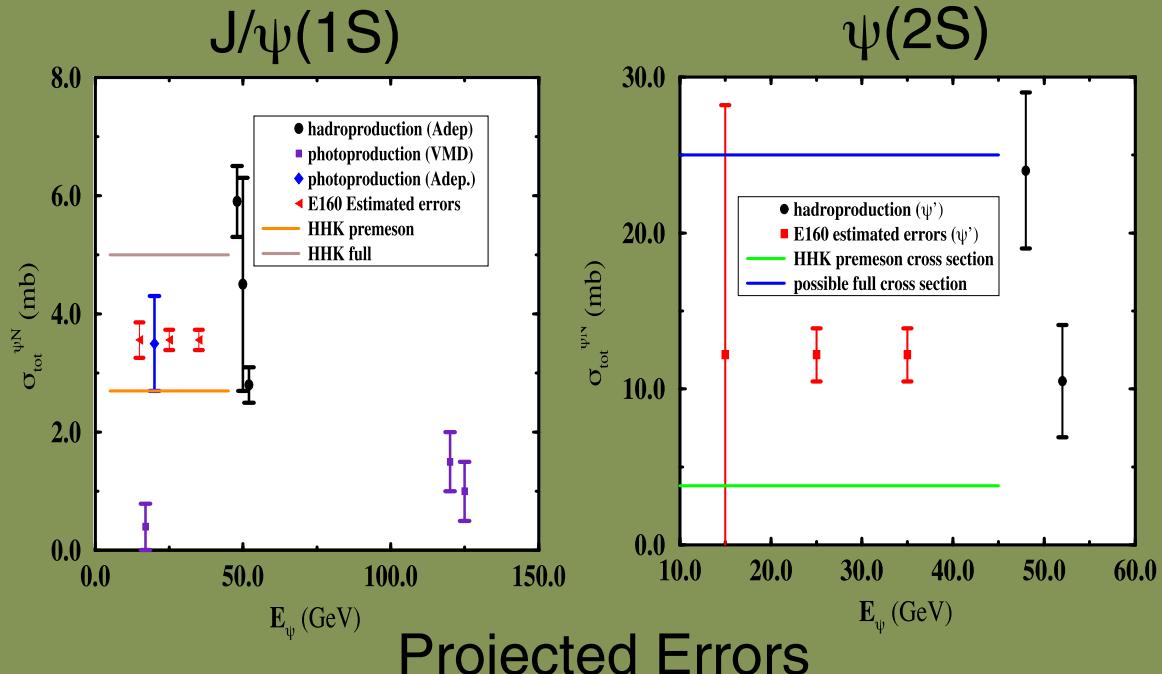
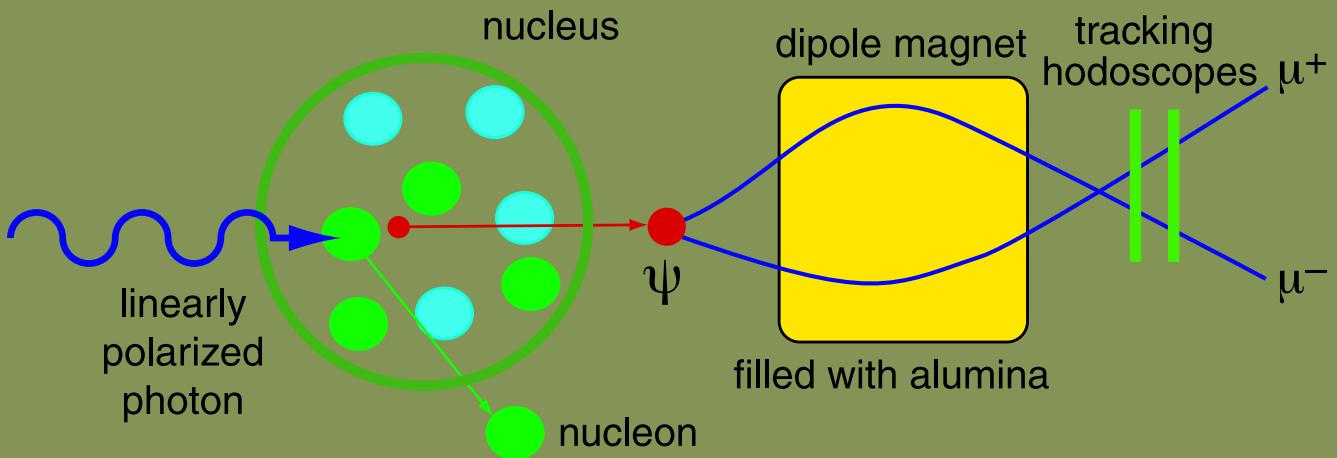
$$\int_{k_\pi}^{\infty} \frac{dk}{k} \Delta \sigma^{\gamma N}(k) = \frac{2\pi^2 \alpha \kappa^2}{M^2}$$

- 10-45 GeV
- LOWER ENERGIES AT JLAB, MAMI, LEGS, GRAAL, ELSA
- NH_3 and ND_3 Targets

E160

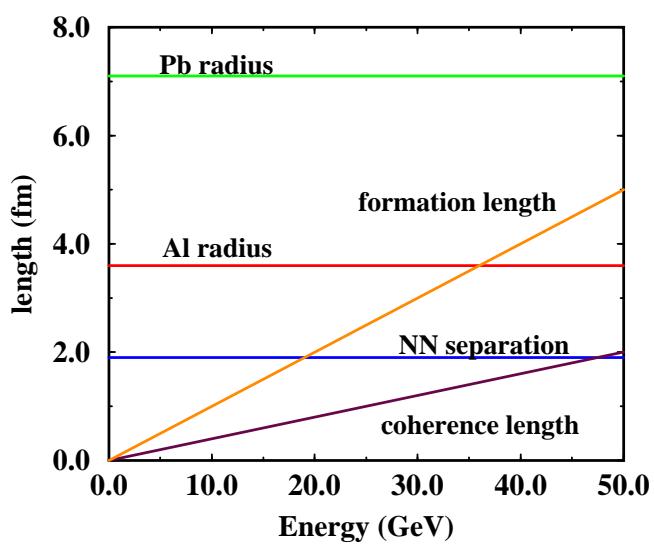
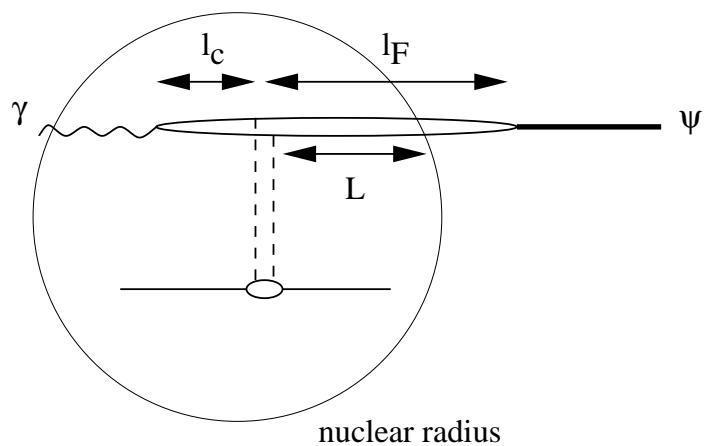
Measurement of the A-Dependence of $J/\psi(1S)$ and $\psi(2S)$ Photoproduction Goals

- 1) Study production and interaction of charmonium in nuclei from Be to Au at energies from 15 to 35 GeV.
- 2) Constrain causes for charmonium suppression in heavy ion collisions.

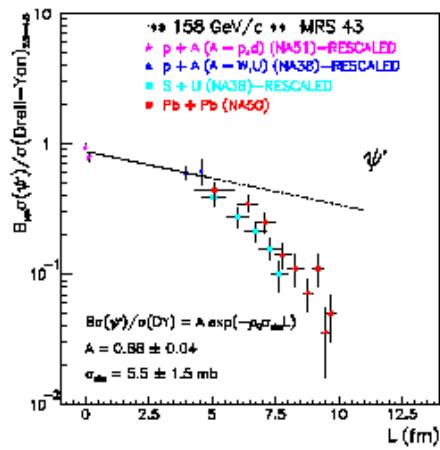
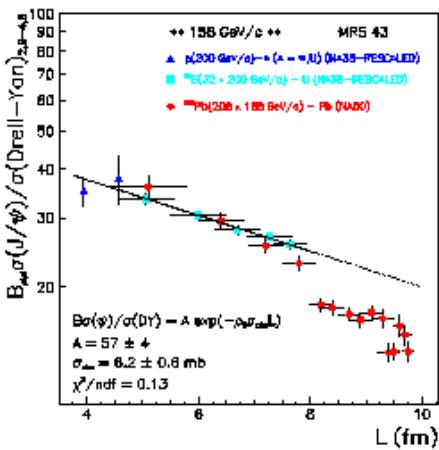


Projected Errors

Length Scales

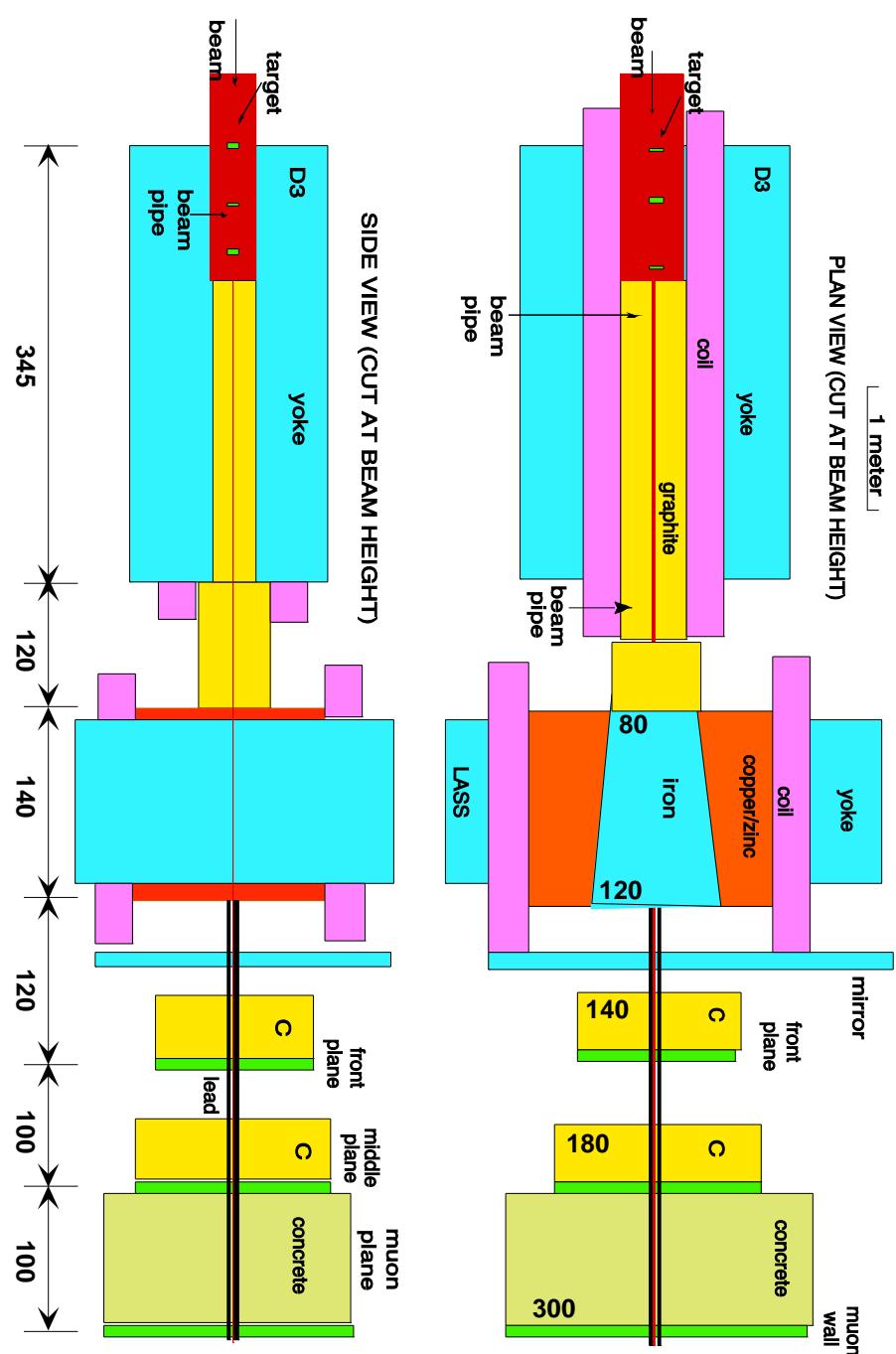


J/ψ Suppression for Heavy Ions



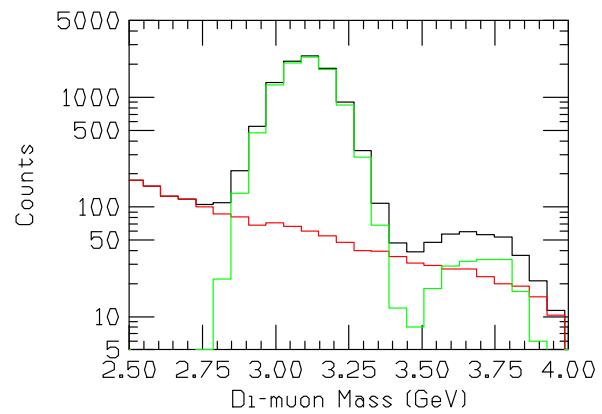
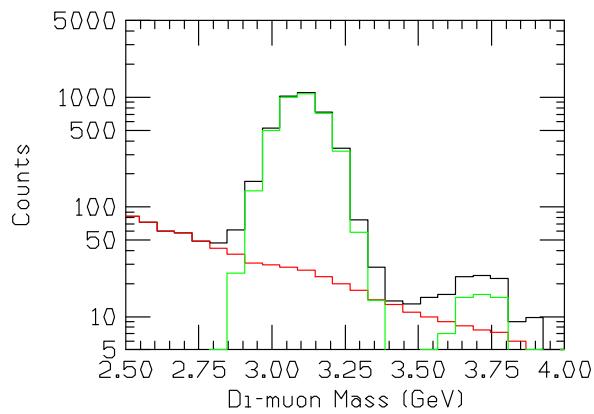
- From B. Müller, nucl-th/980623:
- It's still unclear whether J/ψ is a reliable probe for quark-gluon plasmas.
- Suppression in light targets is the result of the $A^{0.92}$ dependence of the $pA \rightarrow J/\psi X$ cross section.
- The color octet model provides a credible mechanism, but there is no direct evidence for it.
- Available evidence points toward a novel suppression in Pb+Pb collisions.
- Color singlet absorption on hadronic comovers does not explain the Pb+Pb data.

D3+LASS DESIGN: LAYOUT



INVARIANT MASS SPECTRUM AT 25 AND 35 GEV

ψ' and J/ψ peaks clearly separated,
even though 50x less ψ' . No acceptance
for ψ' at 15 GeV. Plots include
Bethe-Heitler background.

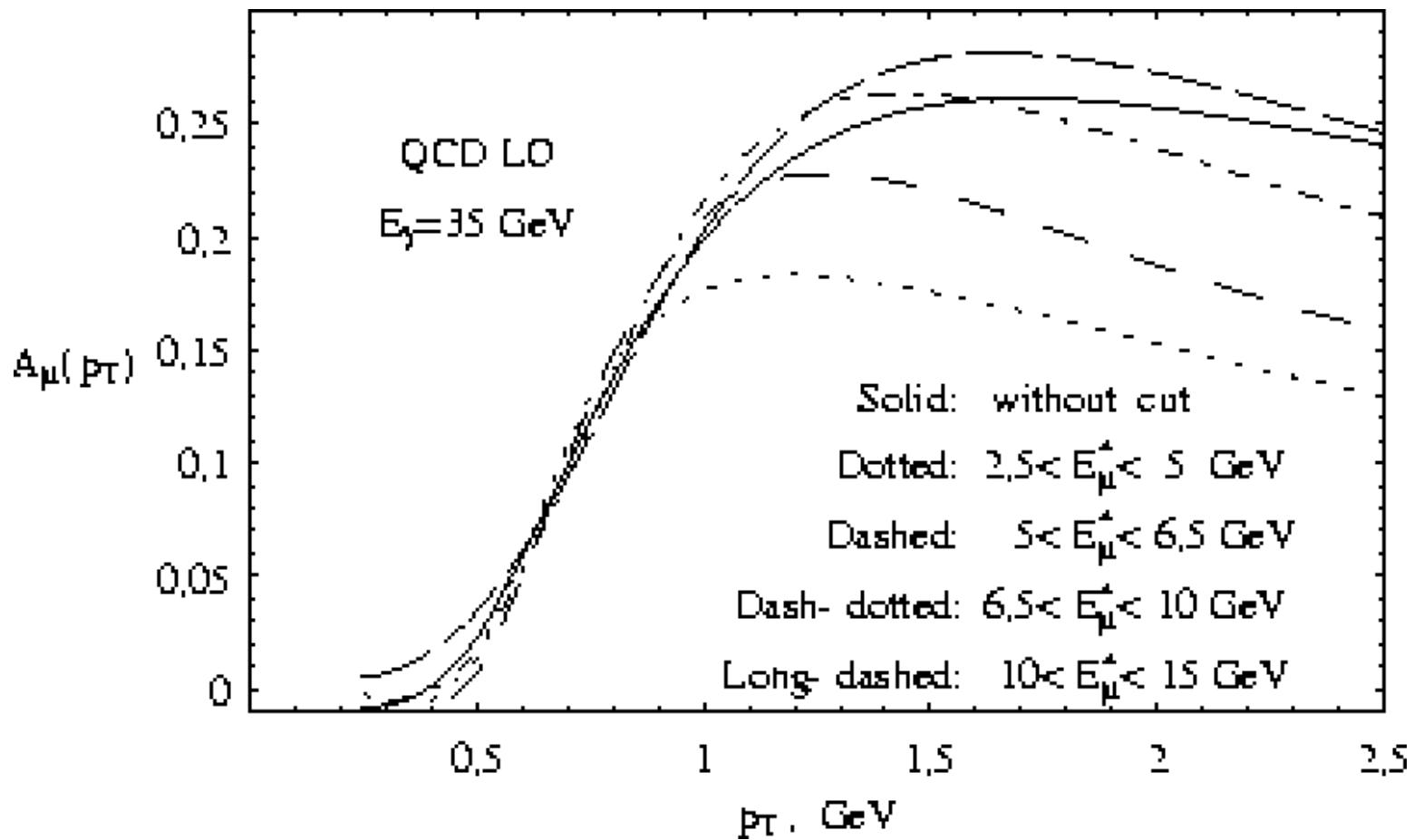


LINEARLY POLARIZED BEAM SINGLE SPIN ASYMMETRY

PHOTON-GLUON FUSION OF OPEN CHARM

- UNPOLARIZED TARGET
- CHARM DECAYS TO MUON
- DETECT SINGLE MUON

Ivanov, Capella, Kaidalov



OPEN CHARM SINGLE SPIN ASYMMETRY

- INSENSITIVE TO CHARM MASS
- INSENSITIVE TO STRANGE MASS
- INSENSITIVE TO INITIAL k_T^2
- INSENSITIVE TO FERMI MOTION
- TINY NLO CORRECTIONS

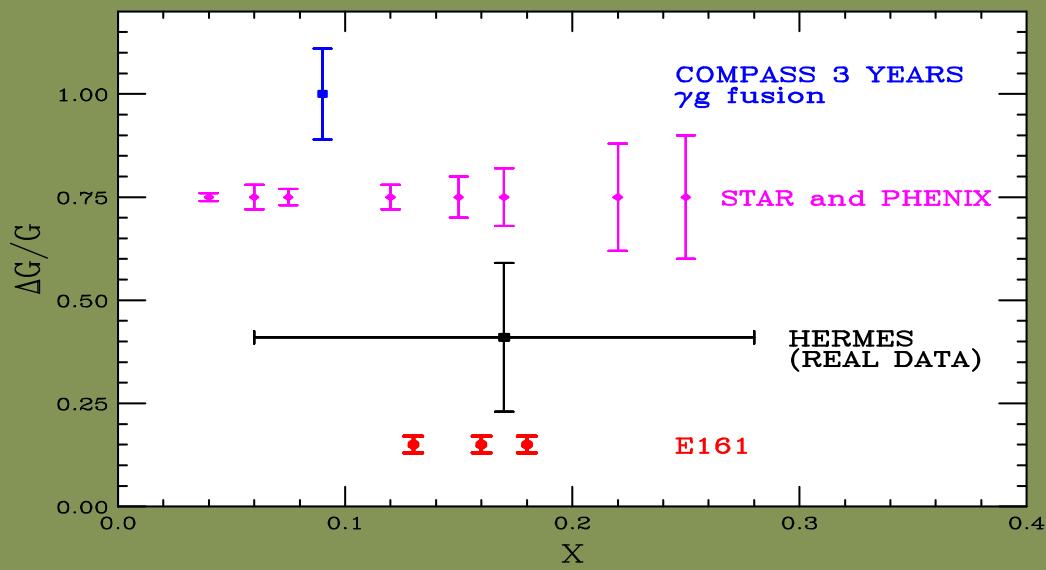
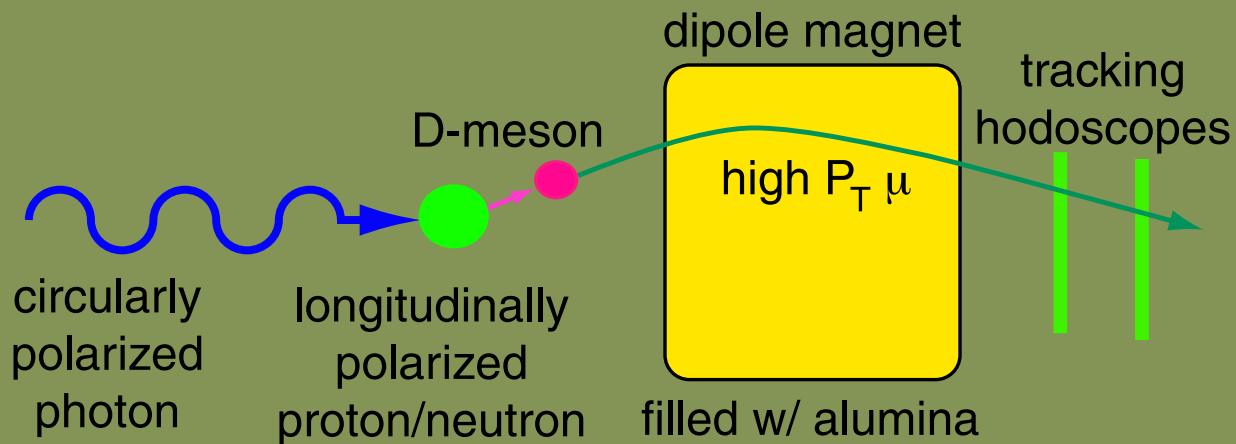
⇒ GOOD TEST OF pQCD IN OPEN CHARM
PHOTO-PRODUCTION

(CROSS SECTION HAS BIG NLO AND m_c EFFECTS)

E161

Gluon Spin in Nucleons Using Polarized Open Charm Photoproduction Goal

Find gluon contribution to the nucleon "Spin Puzzle" using photoproduction of open charm (dominated by photon-gluon fusion diagram). Complementary to measurements at RHIC-Spin and COMPASS.



THE GLUON SPIN STRUCTURE FUNCTION

- **SOME “THEORY”**

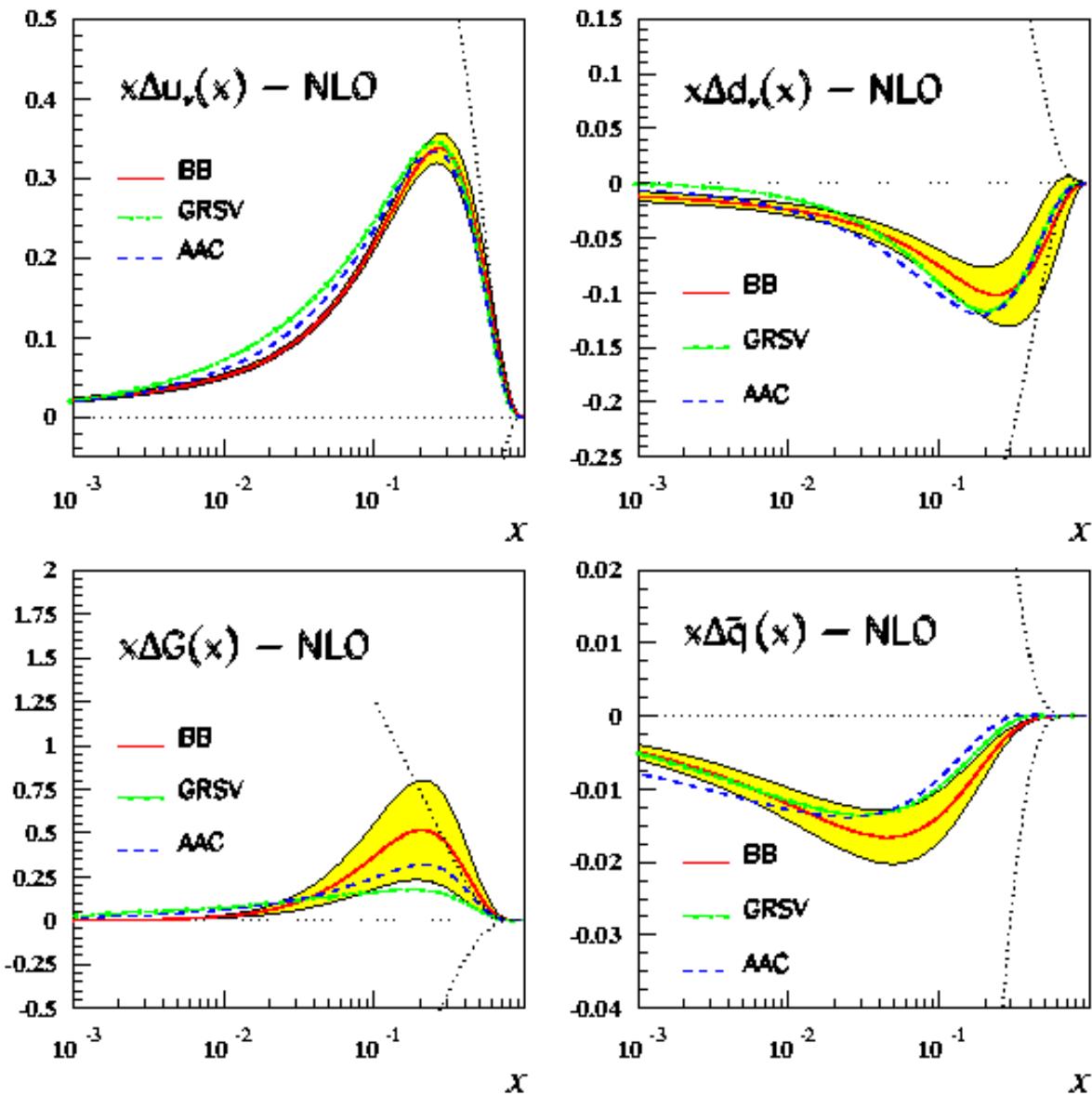
- UNPOLARIZED PARTON DISTRIBUTIONS VERY WELL KNOWN
- POLARIZED VALENCE QUARK DISTRIBUTIONS “WELL KNOWN”
- POLARIZED SEA QUARK DISTRIBUTIONS “POORLY KNOWN”
- POLARIZED GLUON DISTRIBUTION “HARDLY KNOWN”
 - DIS MEASUREMENTS OF POLARIZED STRUCTURE FUNCTION g_1 PUT WEAK LIMITS
 - USE EVOLUTION EQUATIONS TO DETERMINE δG

- **E161 EXPERIMENTAL METHOD**

- PHOTON-GLUON FUSION
- POLARIZED PHOTON BEAM
- POLARIZED TARGET
- CHARM DECAY $\rightarrow \mu$
- MUON DETECTION

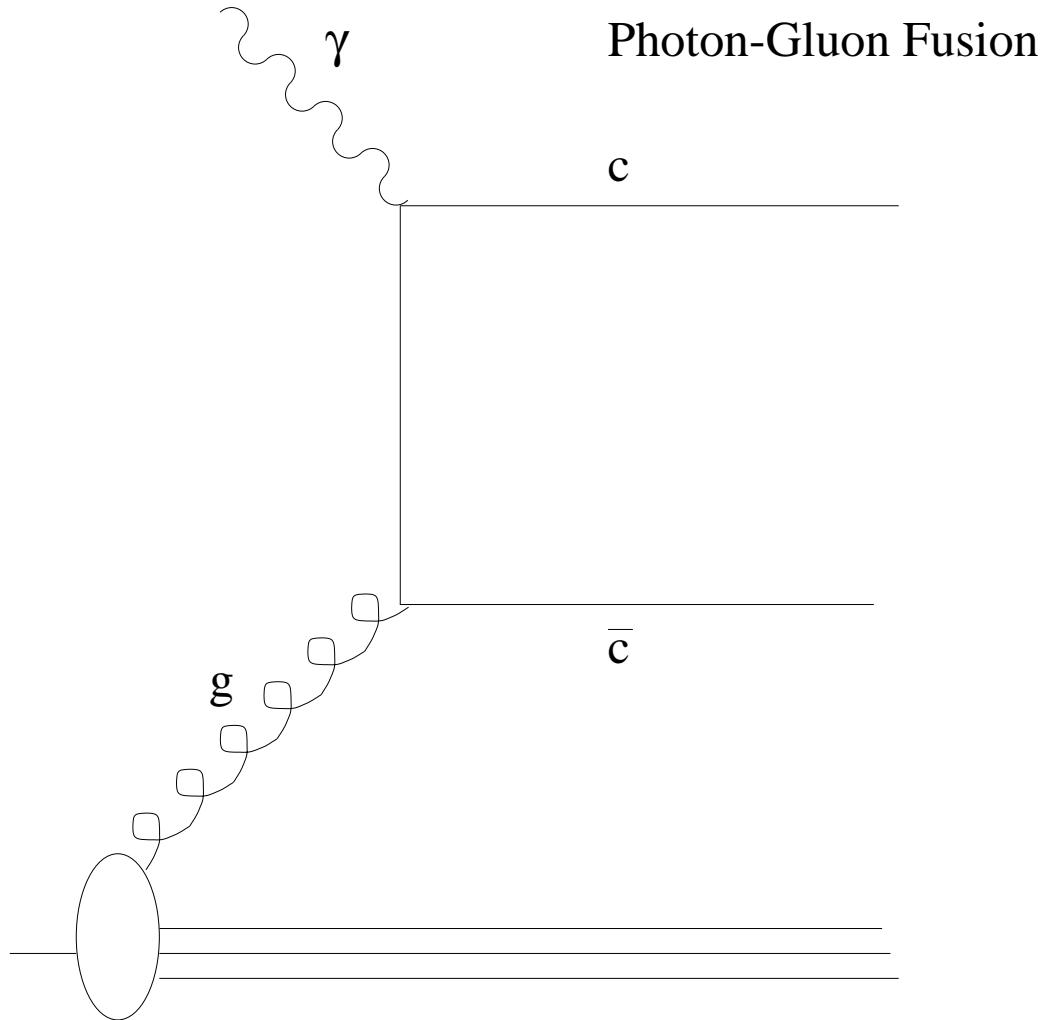
NLO pQCD FIT TO g_1 DATA

BLUMLEIN and Bottcher (2001)

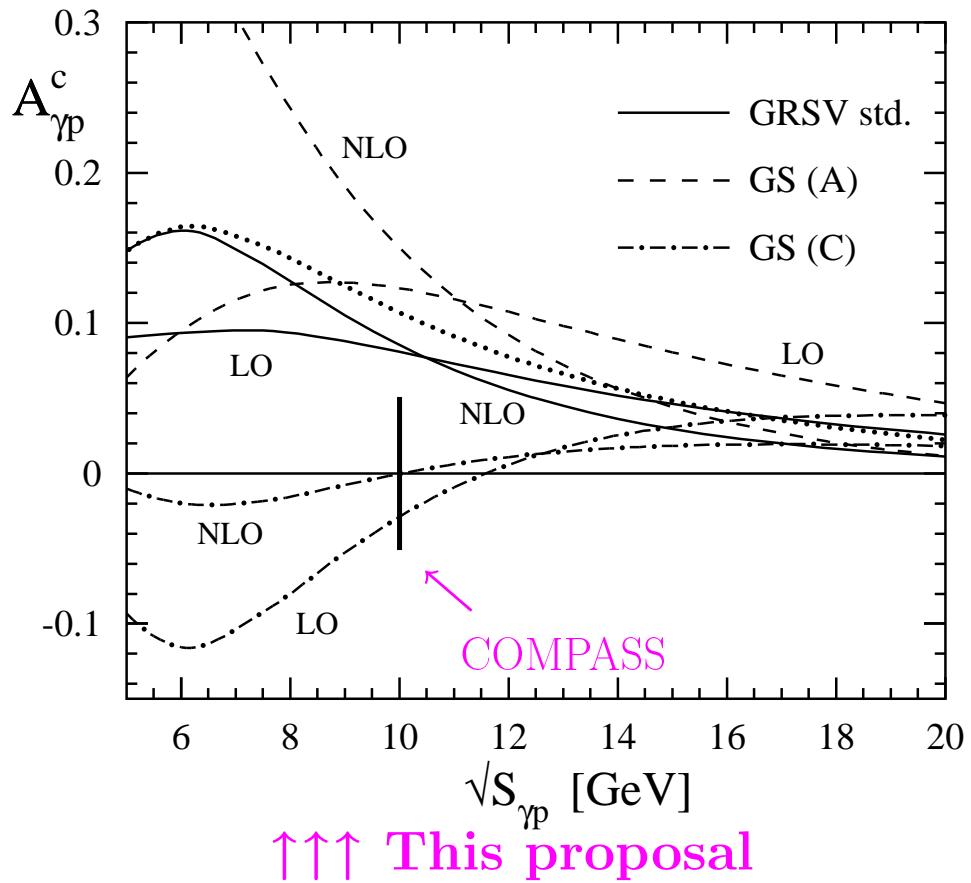


HOW TO MEASURE $\Delta g(x, Q^2)$ DIRECTLY

POLARIZED PHOTON BEAM
POLARIZED LiD TARGET
PHOTON-GLUON FUSION



NLO pQCD



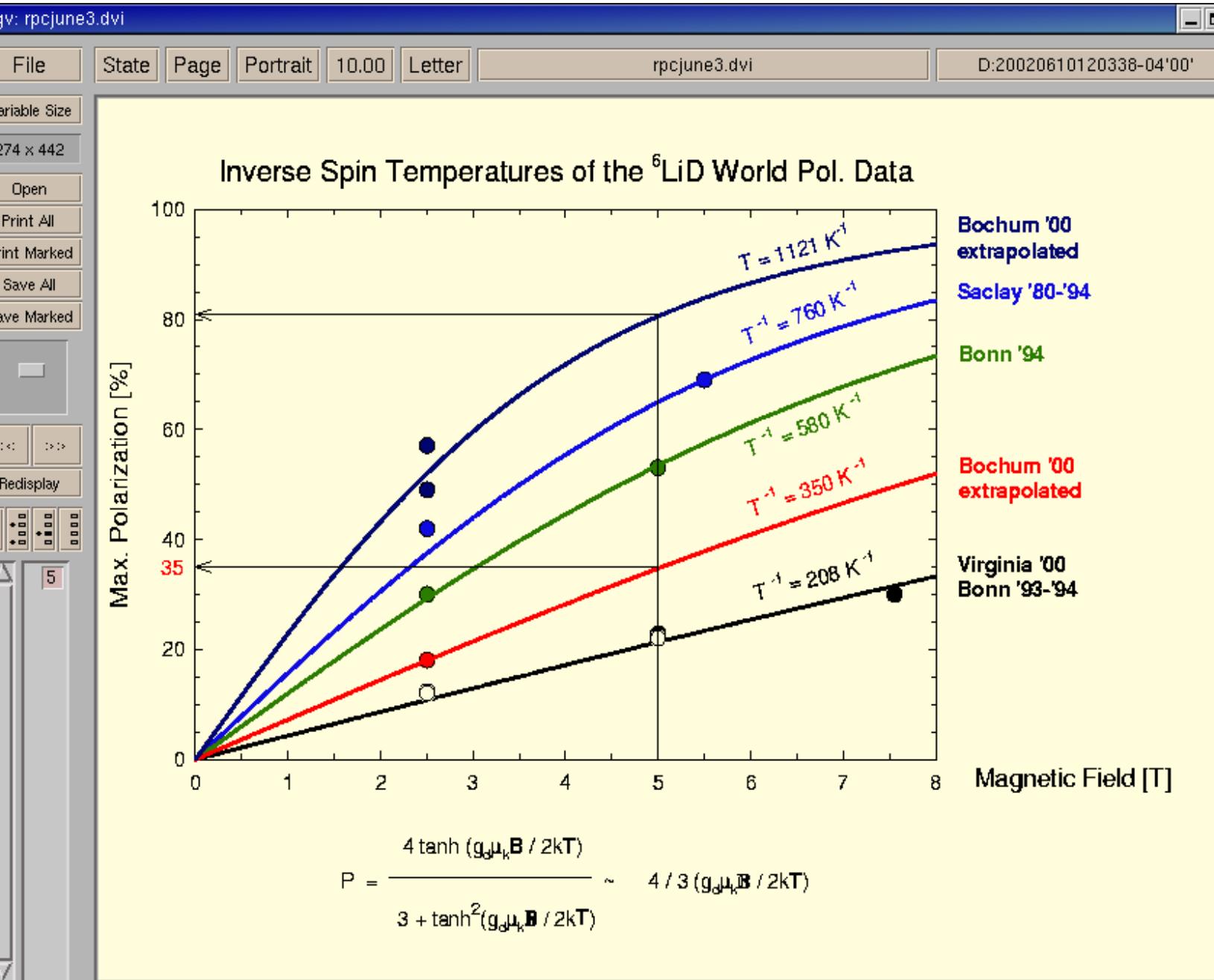
(I. Bojak and M. Stratmann)
also calculated by Z. Merebashvili et al.

IMPORTANT COMPARISON

- MEASURE δG AT POLARIZED RHIC ($p + p$)
- MEASURE δG AT SLAC, COMPASS, HERMES
- COMPARE RESULTS
 - TEST THEORY
 - TEST EXPERIMENTAL METHODS

POLARIZED LiD TARGET

- Photon Beam Allows Low Temperature
- New 7 T magnet
- LiD for Lowest Z (B-H Pairs)
- 70% POLARIZATION



BACKGROUNDS

OTHER SOURCES OF μ

- μ FROM K and π DECAY (Long Lifetime)
- Bethe-Heitler μ PAIRS
- J/ ψ DECAY (Small)
- VECTOR MESON DECAYS (Small)

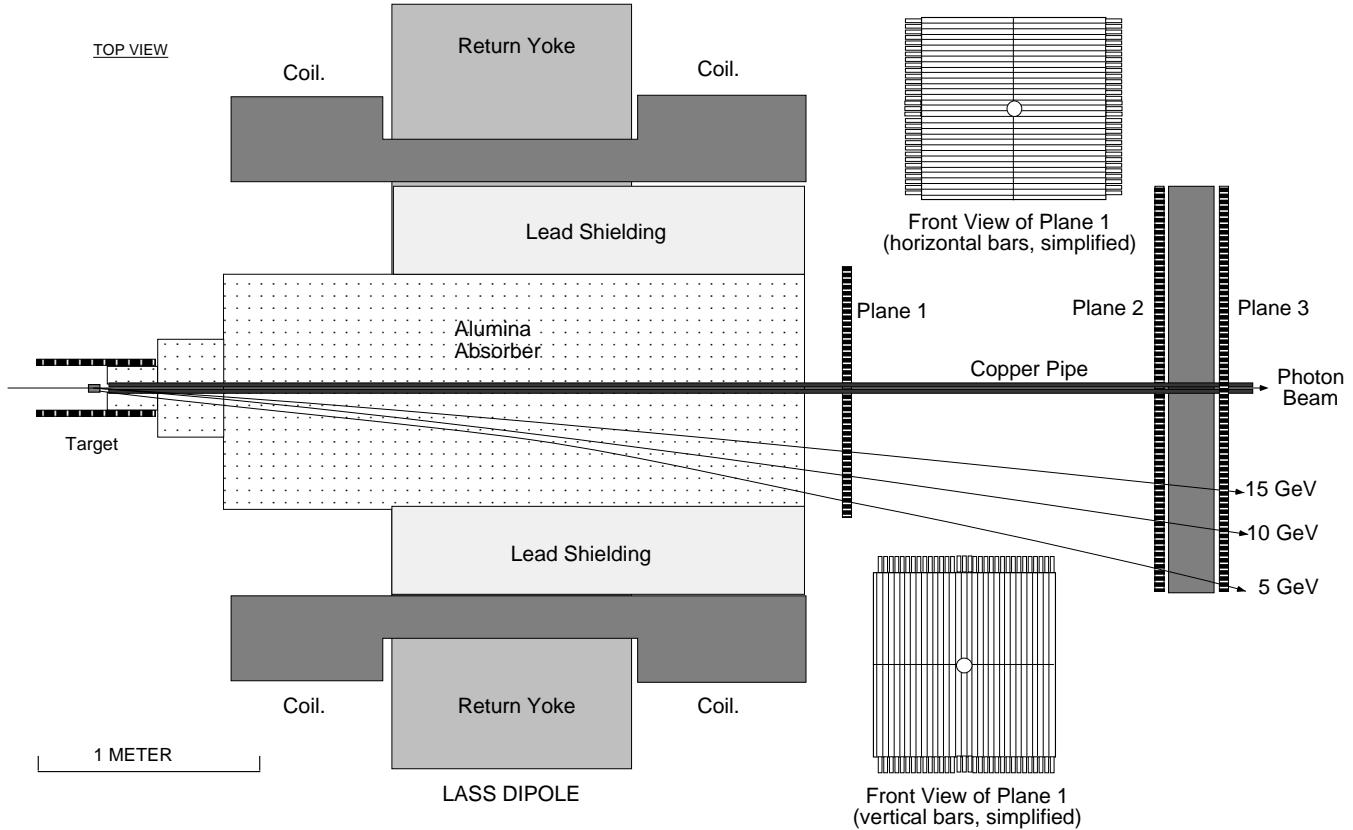
PHYSICS BACKGROUND

- ASSOCIATED PRODUCTION (Small)
- FINAL STATE INTERACTIONS (Small)
- DIFFRACTIVE PRODUCTION (Small)

EXPERIMENTAL STRATEGY

- **HIGH POLARIZATION TARGET**
- **HIGH POLARIZATION BEAM**
- **MEASURE MOMENTUM of μ**
 - High Field Magnet
 - Fine Grain Hodoscopes
 - Good Time Resolution
- **ABSORB K and π BEFORE DECAY**
 - ~ 10 Interaction Lengths (38 R.L.)
 - Monte Carlo Predicts Rates
 - Asymmetry Very Small (E155)
 - Two Absorber Setups
75% and 25% of Time
 - Multiple Scattering of μ Almost the Same
- **VETO $\mu^+ \mu^-$ PAIRS
(B-H, J/ ψ , VECTOR MESONS)**
 - Some Singles Remain (Acceptance)
 - Calculate Based on Pairs and Known σ

DETECTOR FOR OPEN CHARM

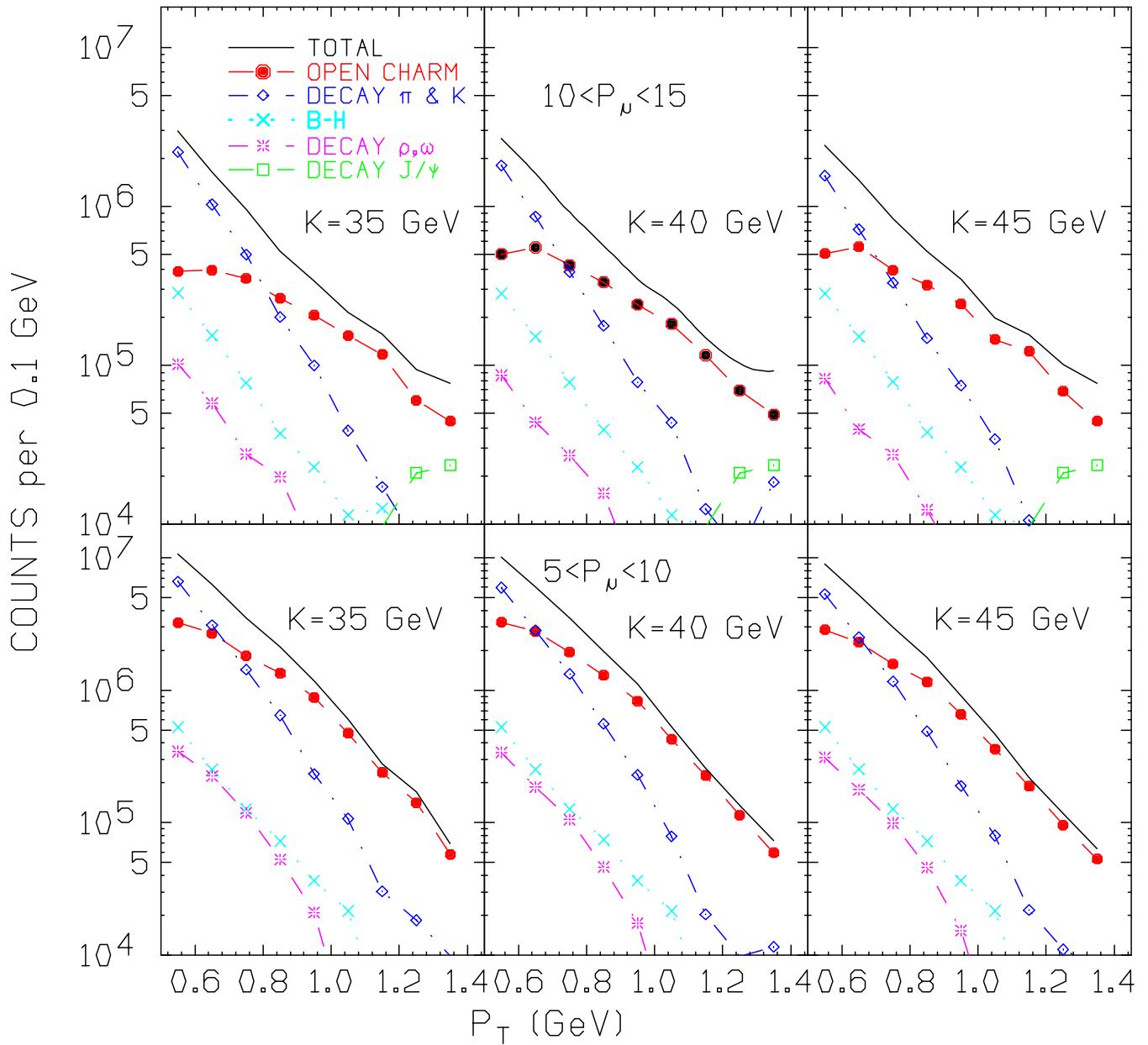


Overall plan view of the main components of the spectrometer. The absorber fills most of the gap of the LASS dipole, and also extends into the warm bore of the target magnet. A thick evacuated copper beam pipe contains the photon beam. The three detector planes are made from scintillator hodoscopes. Two simplified front views of the front plane are shown. The dashed curves are typical trajectories for muons with $p_t = 0.7$ and $P = 5, 10$, and 15 GeV.

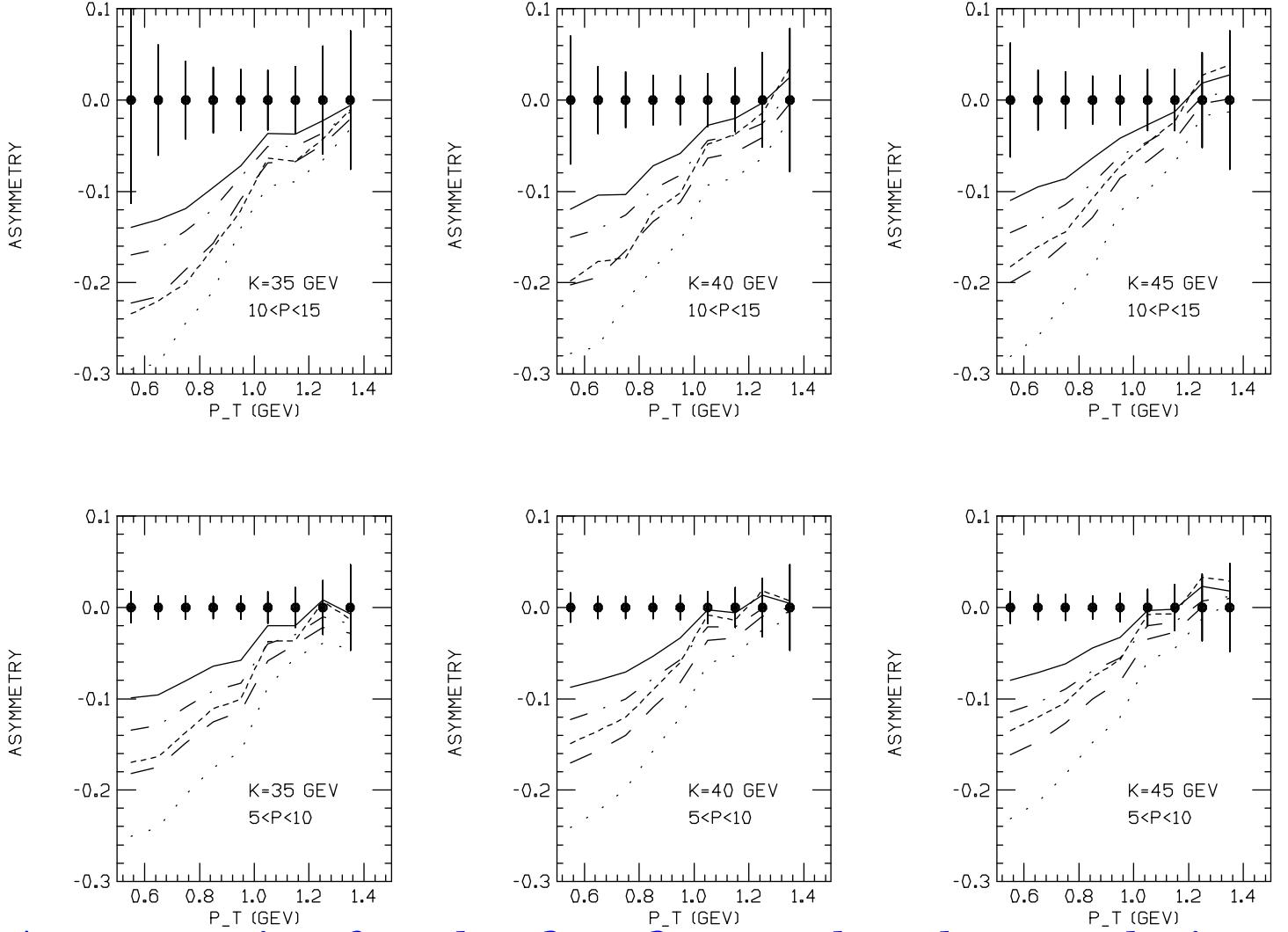
NUMBER OF EXPECTED SINGLE μ

SIGNAL and BACKGROUNDS

BEFORE BACKGROUND SUBTRACTION

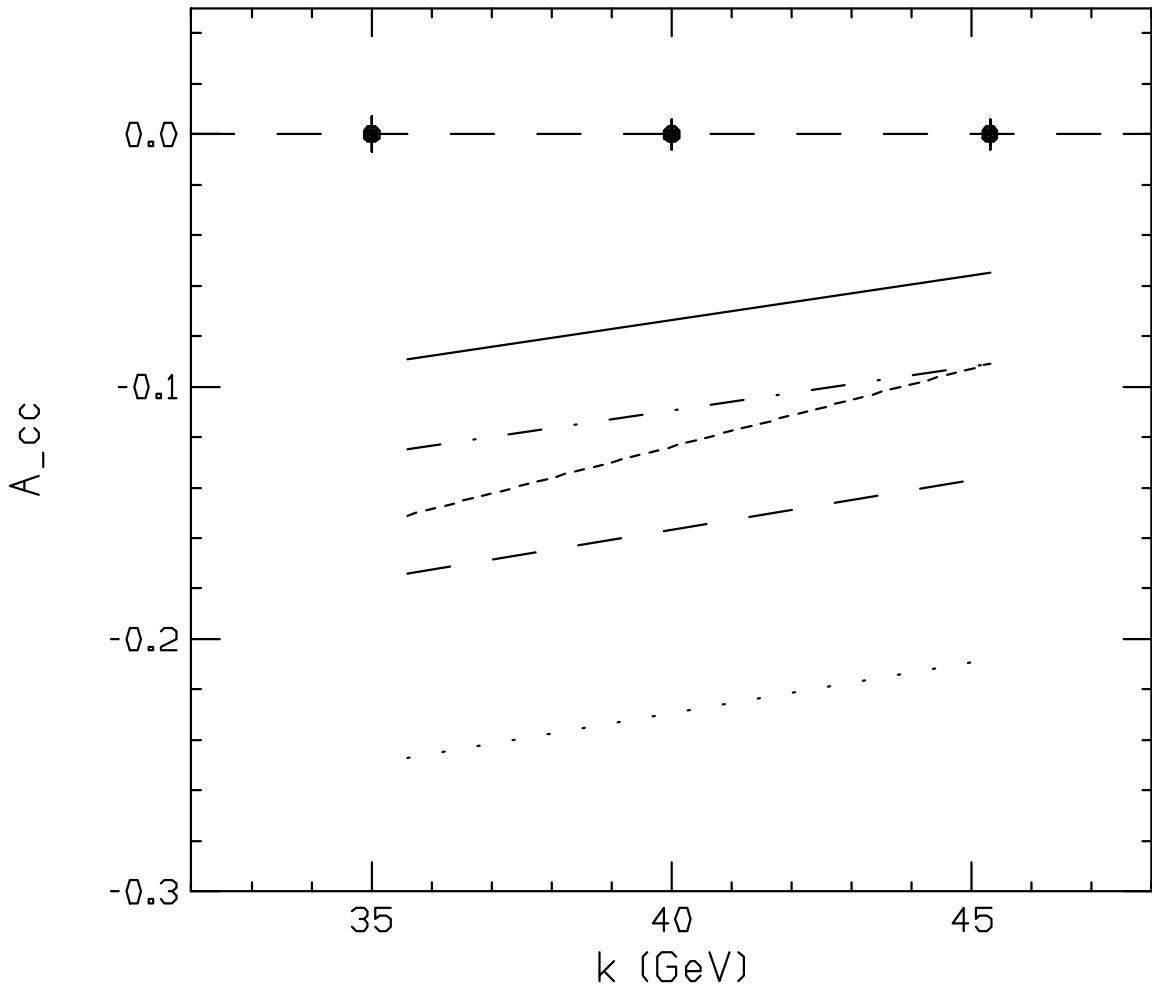


EXPECTED ERRORS



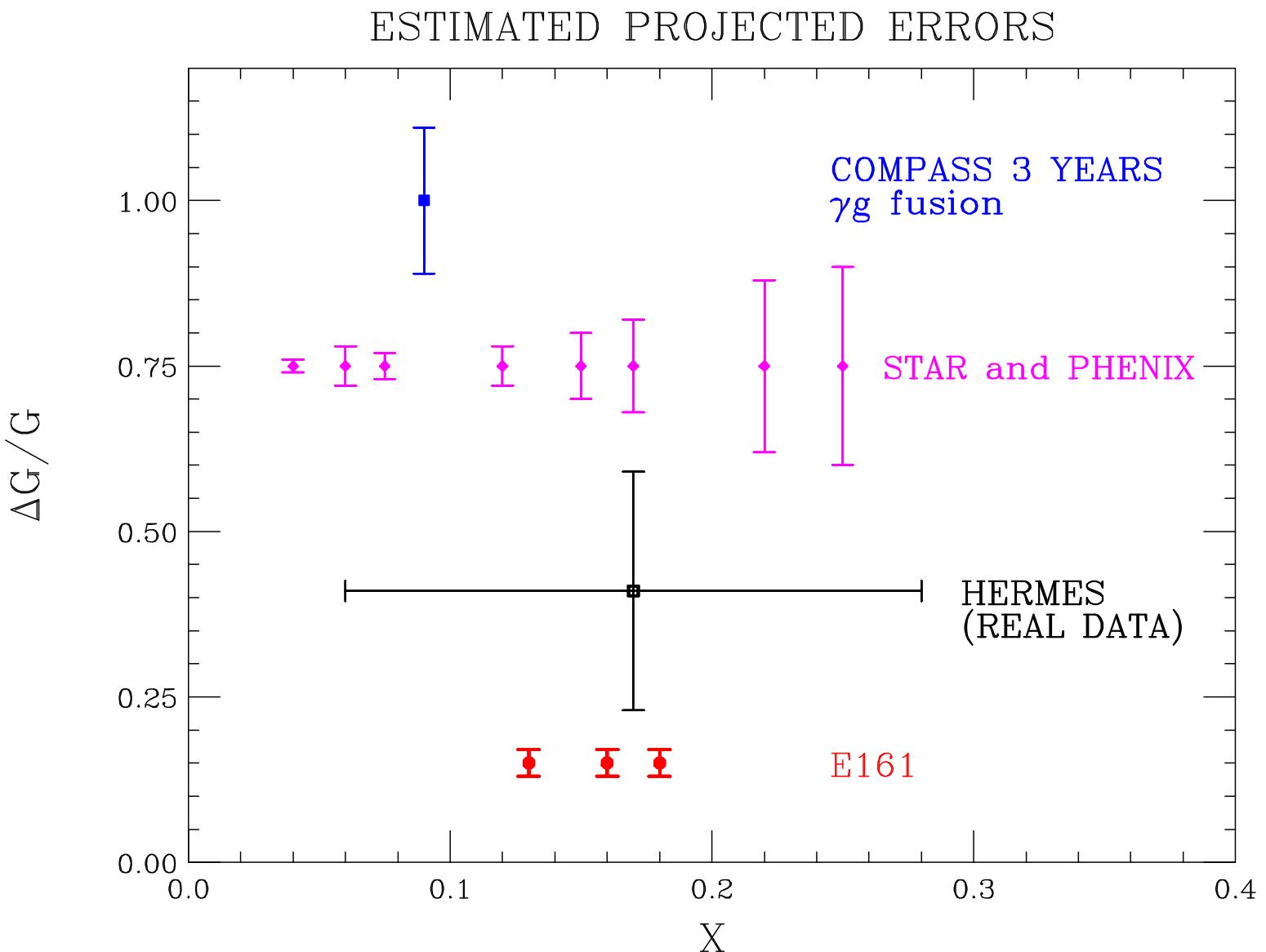
Asymmetries for the five fits to the gluon polarization as a function of p_T^μ of the detected muon. The top row is for $10 < P_\mu < 15 \text{ GeV}$ and the bottom row for $5 < P_\mu < 10$. The three columns correspond to peak beam energies of 35, 40 and 45 Gev. The points indicate the projected statistical errors. Experimental systematic errors will be highly correlated from point-to-point, and will be approximately 0.10 of the measured asymmetries.

AVERAGE EXPECTED ERRORS



Asymmetries for the five fits to the gluon polarization as a function of beam energy. The points, arbitrarily placed at zero asymmetry, indicate the projected statistical errors for the running conditions given in the text, averaged over p_T .

COMPARISON OF EXPERIMENTS



ALTERNATE METHODS

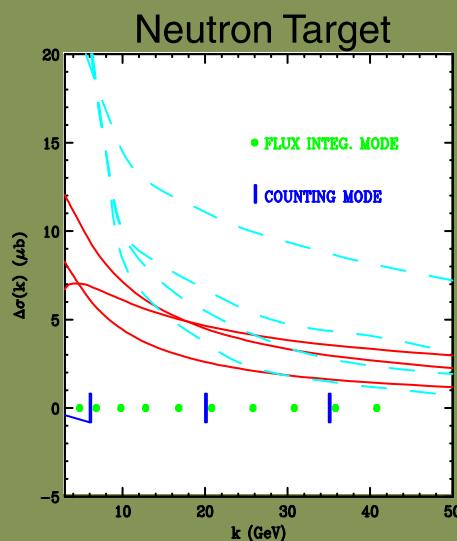
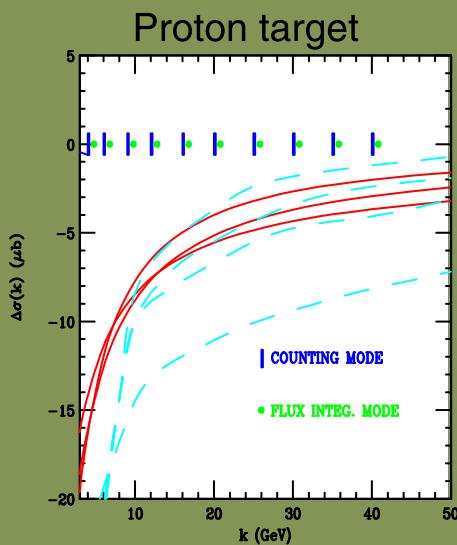
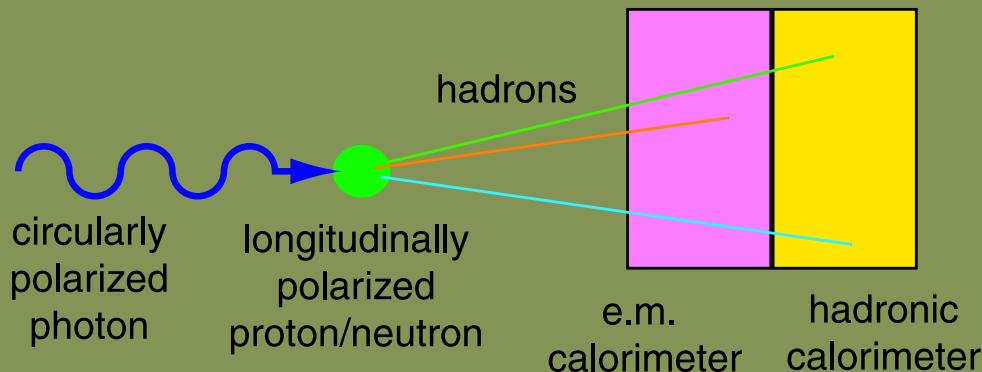
- HIGHER INTENSITY PHOTON BEAM ($\times 50$)
 - HIGHER INTENSITY ELECTRON BEAM
 - THICKER DIAMOND
- DETECT J/ψ (Some Theory Problems)
- DETECT μ^+ and μ^- FROM c and \bar{c}
 - LOWER BACKGROUNDS OF SOME KINDS.
 - HIGHER BACKGROUNDS OF OTHER KINDS.

E159

Measurement of $\Delta\sigma(k)$ and the High Energy Contribution to the GDH Sum

Goals

- 1) Measure helicity dependence of cross section to absorb circularly polarized photons on polarized nucleons in the energy range 5 to 45 GeV.
- 2) Test the fundamental GDH Sum Rule.



Projected Errors

INTRODUCTION

- Total photoabsorption cross section $\sigma^{\gamma N}(k)$ depends only on photon energy k for real photons.
- Can be decomposed into spin 1/2 and 3/2 final states $\sigma_{3/2}$ and $\sigma_{1/2}$, corresponding to helicity of photon aligned or anti-aligned with spin of nucleon.
- Spin-averaged $\sigma^{\gamma N}(k) = (\sigma_{1/2} + \sigma_{3/2})/2$ well-measured (including SLAC early 1970's). Roughly constant at 120 μb .
- We propose to measure

$$\Delta\sigma^{\gamma N}(k) = \sigma_{3/2} - \sigma_{1/2}$$

using circularly polarized photons and longitudinally polarized nucleons.

The GDH SUM RULE

- Relates integral over $\Delta\sigma(k)$ to anomalous magnetic moment κ of target with spin S (composite or elementary).

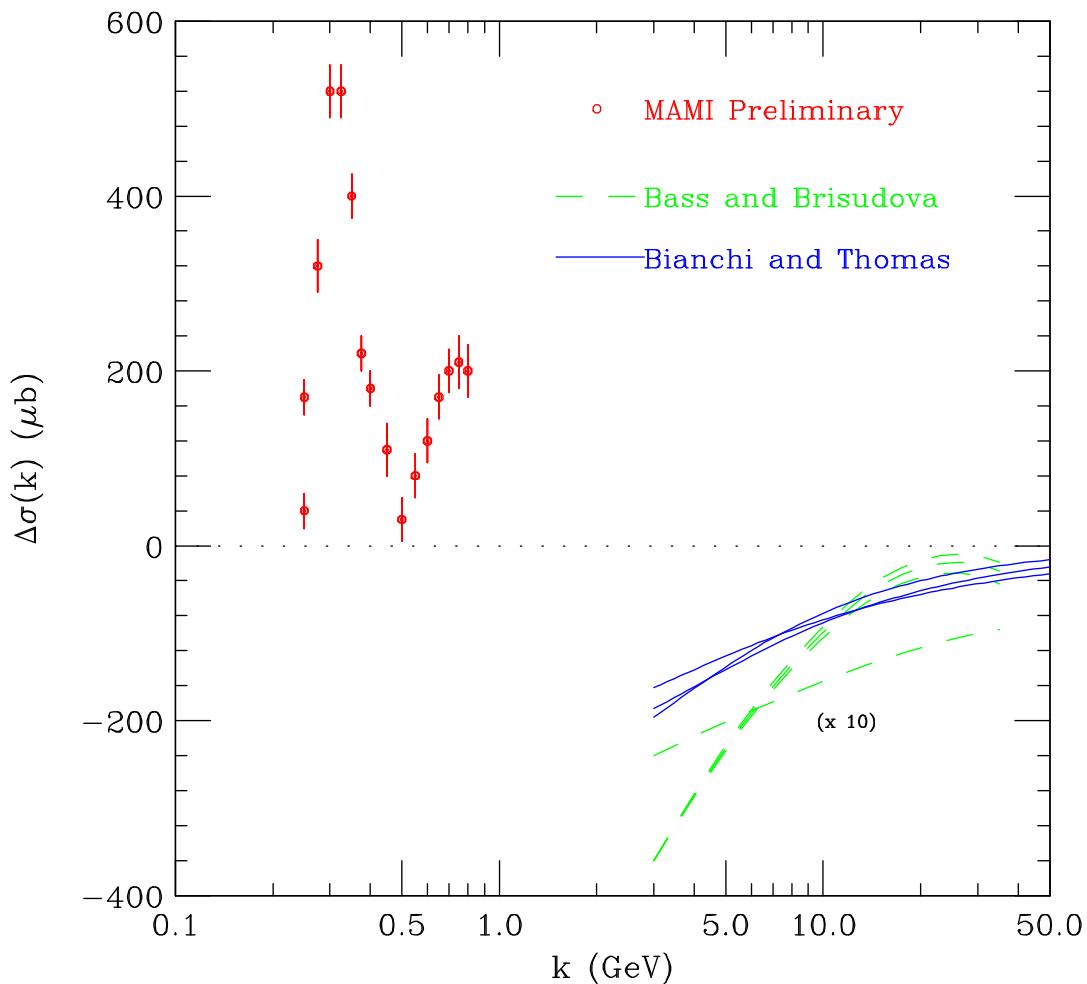
$$\int_{k_\pi}^\infty \frac{dk}{k} \Delta\sigma^{\gamma N}(k) = \frac{2\pi^2 \alpha \kappa^2}{M^2}$$

- Follows from general principles of causality, universality, Lorentz and electromagnetic gauge invariance.
- One assumption: that unsubtracted dispersion relation can be used for $f_2(\nu)$ (the spin-dependent part of the forward Compton amplitude).
- Theorists debate whether a $J = 1$ fixed pole (violating GDH Sum Rule and possibly Bjorken Sum Rule also) is likely, unlikely, or ruled out in QCD.

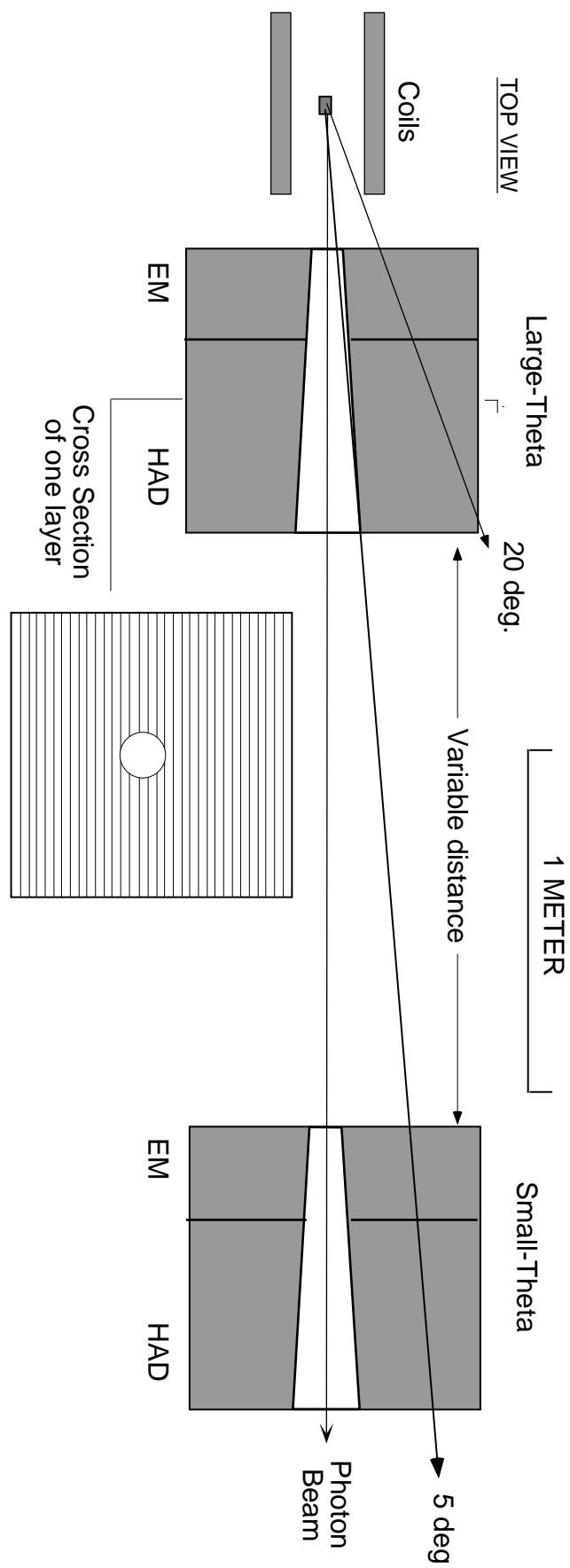
LOW ENERGY BEHAVIOR OF $\Delta\sigma(k)$

Preliminary data from Mainz on proton.

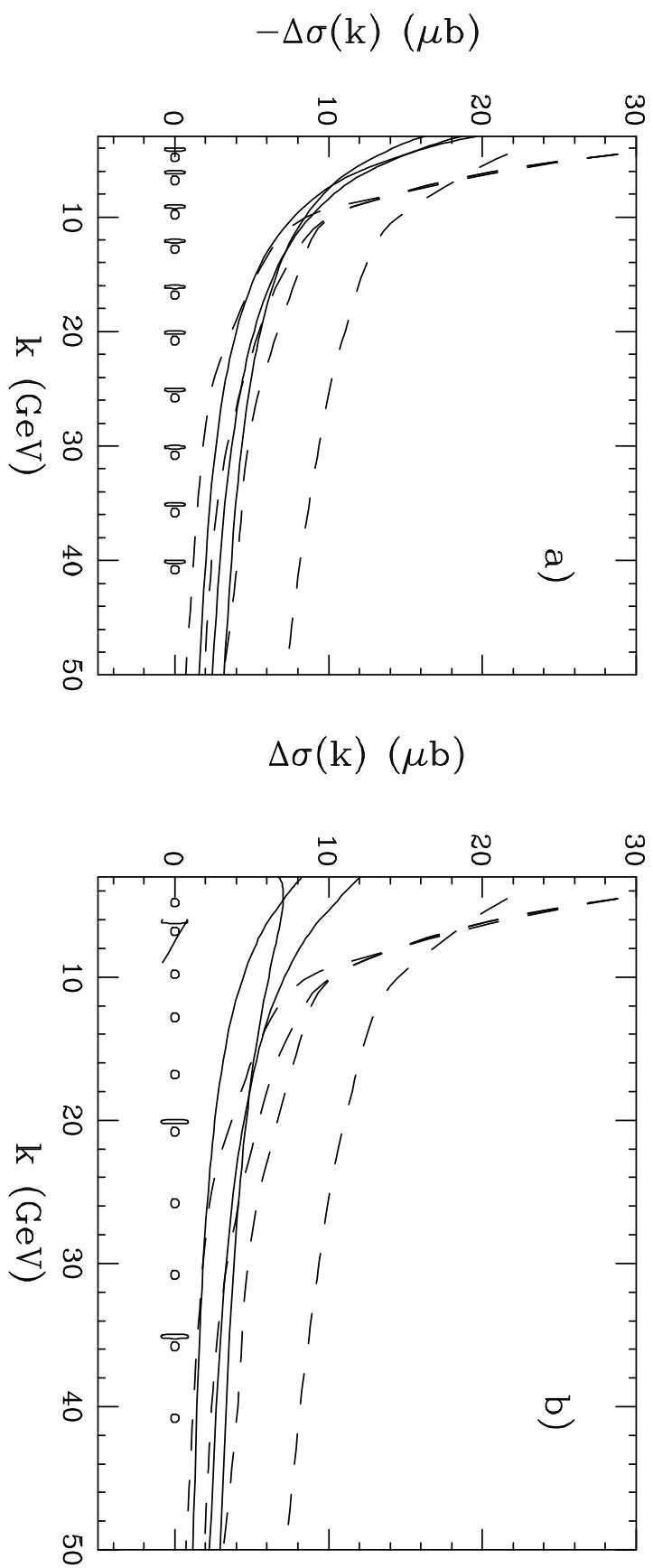
Resonant excitations are evident (especially $\Delta(1232)$).



GDH SUM RULE DETECTOR



GDH: ASYMMETRY ERRORS



Estimated a) proton b) neutron errors for $\Delta\sigma^{\gamma p}(\mathbf{k})$ for this proposal as a function of photon energy for the counting mode (rectangles) and flux integration mode (circles). The symbol heights represent the expected statistical errors in the more conservative analysis. Systematic errors are not shown, but are expected to be 6% to 8% of the measured values of $\Delta\sigma^{\gamma N}(\mathbf{k})$. The dashed curves are representative models.

SUMMARY

- NEW COHERENT QUASI-MONO-ENERGETIC POLARIZED PHOTON BEAM
- 3 APPROVED FIXED TARGET EXPERIMENTS
- POSSIBLE LONGITUDINAL SINGLE SPIN CHARM PRODUCTION pQCD TEST
- HOWEVER NEED MONEY TO PAY FOR ELECTRICITY
 - ENRON SCREWED UP CALIFORNIA ENERGY COSTS